GROUNDWATER INFORMATION SHEET

Hexavalent Chromium

The purpose of this fact sheet is to provide general information regarding a specific constituent of concern (COC). The following information, compiled by staff of the Groundwater Ambient Monitoring and Assessment (GAMA) Program, is pulled from a variety of sources and relates mainly to drinking water. For additional information, the reader is encouraged to consult the references cited at the end of this information sheet.

GENERAL INFORMATION	
Constituent of Concern	Hexavalent Chromium
Aliases	Chromium VI, Chromium Six, Chrome 6, Cr^6
Chemical Formula	Cr^6
CAS No.	185440-29-9
Storet No.	01032
Summary	The California Department of Public Health (CDPH) included hexavalent chromium as an unregulated chemical requiring monitoring in 2001. Based on recent data, 3,107 of 6,565 public wells have concentrations above the detection limit for purposes of reporting (DLR) of 1µg/L. Most detections of hexavalent chromium have occurred in Los Angeles, San Bernardino and Fresno Counties. A Public Health Goal (PHG) of 0.02 µg/L was published in July 2011.

HEXAVALENT CHROMIUM REGULATORY AND WATER QUALITY LEVELS[1]		
Type	Agency	Concentration
Federal MCL	US EPA, Region 9	None established
State MCL	CDPH	In process
DLR	CDPH	1 μg/L
PHG	OEHHA	0.02 μg/L
Preliminary Remediation Goal (PRG) IRIS (non-cancer health effect)	US EPA, Region 9 US EPA, Region 9	100 μg/L 21 μg/L

[1]These levels generally relate to drinking water, other water quality levels may exist. For further information, see *Water Quality Goals* (Marshack, 2011).
MCL = Maximum Contaminant Level
US EPA = United States Environmental Protection Agency
OEHHA = Office of Environmental Health and Human Hazard Assessment
IRIS = Integrated Risk Information system

SUMMARY OF HEXAVALENT CHROMIUM DETECTIONS IN PUBLIC DRINKING WATER WELLS[2]	
Detection Type	**Number of Groundwater Sources**
Number of active and standby public water wells with Cr^6 concentrations > 1 μg/L.	3,107 of 6,565 public wells tested
Top 3 counties having public water wells with Cr^6 concentrations > 1 μg/L.	Los Angeles, San Bernardino, Fresno

[2]Based on CDPH data collected from 2000-2011 (GeoTracker GAMA). Drinking water supplied from active and standby public water wells is typically treated and/or blended. Individual wells and wells for small water systems not regulated by CDPH are not included.

ANALYTICAL INFORMATION		
Method	**Detection Limit**	**Note**
Graphite Furnace atomic absorption spectrometry (GFAAS) and inductively coupled plasma mass spectroscopy (ICP-MS (screening methods)	1 μg/L	CDPH approved for public drinking water systems
US EPA 218.6	0.2 μg/L	CDPH approved
USGS by GFAAS	0.05 μg/L	Cr^6 separation in the field, not time sensitive
Known limitations to Analytical Methods	Water sample pH must be adjusted to 9.0-9.5, stored at 4° C and analyzed within 24 hours.	
Public Drinking Water Testing Requirements	In January 2001, CDPH identified hexavalent chromium as an unregulated chemical requiring monitoring. As a result, public water systems began to test for hexavalent chromium in their drinking water supplies to the DLR of 1 μg/L.	

OCCURRENCE	
Anthropogenic Sources	Chromium is a metallic chemical that originates as a contaminant in the environment from the discharges of dye and paint pigments, wood preservatives, chrome-plating liquid wastes, and leaching from hazardous waste sites. The greatest use of chromium is in metal alloys such as stainless steel; protective coatings on metal; magnetic tapes; and pigments for paints, cement, paper, rubber, composition floor covering, etc. The two largest sources of chromium emission in the atmosphere are from the chemical manufacturing and combustion of natural gas, oil and coal.
Natural Sources	Chromium is a metal found in natural deposits of ores containing other elements, mostly as chrome-iron ore. It is also widely present in soil and plants. Under most conditions, natural chromium in the environment occurs as Cr^3. Under oxidizing conditions, alkaline pH range, presence of MnO_2 and minerals containing chromium, part of it may occur as hexavalent chromium dissolved in groundwater. Recent sampling of drinking water throughout California suggests that hexavalent chromium may occur naturally in groundwater at many

	locations. Naturally occurring hexavalent chromium may be associated with serpentinite-containing rock or chromium containing geologic formations.
History of Occurrence	Hexavalent chromium has been found in groundwater at several industrial sites where wood treatment or metal plating solutions were used. Hexavalent chromium contaminating groundwater became well known after Pacific Gas & Electric (PG&E) was accused by residents of contaminating groundwater in the Hinkley community, west of Barstow. Hexavalent chromium was used to reduce corrosion in a natural gas compressor plant. Contaminated water was suspected of causing cancer and tumors in Hinkley residents. Since then, hexavalent chromium has been found at elevated concentrations in groundwater at several locations in California; Glendale, Topock and Kettleman City. Hexavalent chromium occurs naturally in groundwater at the Presidio of San Francisco and Lawrence Livermore National Laboratory. As of August 2011, hexavalent chromium has been reported at concentrations above 1 μg/L in 3,107 active and standby public wells out of 6,565 wells sampled. Elevated concentrations of hexavalent chromium have been found in Los Angeles (524 μg/L), Humboldt (93 μg/L), San Bernardino (85 μg/L), Santa Barbara (43 μg/L), and Yolo (54 μg/L) counties.
Transport Characteristics	Hexavalent chromium is readily soluble in water. Under high Eh (oxidizing) and alkaline (pH above 7) conditions, hexavalent chromium can be predominant in groundwater. However, in the presence of organic matter, ferrous iron (Fe II) and sulfide, hexavalent chromium can be readily reduced to Cr^3 and immobilized. Adsorption of hexavalent chromium by clayey soil and natural aquifer materials is low to moderate under near-neutral pH ranges commonly encountered in groundwater.

REMEDIATION & TREATMENT TECHNOLOGIES

In-situ Treatment:
In several laboratory and field pilot tests, and full-scale remediation systems, hexavalent chromium has been removed using a permeable reactive barrier filled with zero-valent iron granules, surfactant-modified zeolite or by injection of sodium dithionite. Other methods include geochemical fixation, soil flushing and extraction, bioremediation and electrokinetics. Also, the use of tin is being proposed to reduce Cr^6 to Cr^3 in the San Gabriel basin as part of a process for the production of potable water.

Above-Ground Treatment
Drinking water can be treated by different pump and treat remediation systems. Cr^3 and Cr^6 can be removed by reverse osmosis or ion exchange resin. The ion exchange method should be used with caution, as presence of other metals may interact with the process and decrease system effectiveness. Removal of Cr^6 by seaweed biosorbent and bacteria (Bacillus sp.) within packed bed reactors has also been used.

Natural Attenuation
Natural attenuation of hexavalent chromium may occur in the subsurface environment through reduction by organic matter, iron hydroxides or sulfides. Prior to selection of natural attenuation as an option for remediation, the following conditions need to be demonstrated: 1) there are natural reducers present within the aquifer, 2) the amount of hexavalent chromium and other reactive constituents do not exceed the capacity of the aquifer to reduce them, 3) the rate of hexavalent chromium reduction is greater than the rate of transport of the aqueous hexavalent chromium off the impacted site, 4) the hexavalent chromium remains immobile, and 5) there is no net oxidation of Cr^3 to Cr^6.

HEALTH EFFECT INFORMATION

Hexavalent chromium is known to cause cancer in humans when inhaled. Hexavalent chromium can also damage the lining of the nose and throat and irritate the lungs. A number of scientific studies have found elevated rates of lung cancer in workers with occupational exposure to hexavalent chromium by inhalation. A few studies of workers exposed to hexavalent chromium by inhalation have shown an increase in cancers of the gastrointestinal tract. When swallowed, hexavalent chromium can upset the gastrointestinal tract and damage the liver and kidneys. In recent scientific studies of laboratory animals, hexavalent chromium has been linked to cancer when ingested, although ingested hexavalent chromium is rapidly converted to Cr^3 after entering the stomach and contact with organic matter.

KEY REFERENCES

1. Bohumil Voleski; Removal of Trivalent and Hexavalent Chromium by Seaweed Biosorbent, environmental Science & technology; 1998; 32(18); 2693-2698. (Article)

2. CDPH Chromium 6 (Hexavalent Chromium) in Drinking Water: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chromium6.aspx

3. Dorota Z. Haman, Del B. Bottcher; Home Water Quality and Safety University of Florida, Cooperative Extension Service, Institute of Food and Agricultural Science, http://edis.ifas.ufl.edu/BODY_AE009

4. Montgomery Watson; Technical Memorandum-Hexavalent Chromium in Groundwater, Presidio of San Francisco, prepared for US COE, April 1998

5. OEHHA; Fact Sheet – Final Public Health Goal for Hexavalent Chromium, 07/27/2011. http://www.oehha.ca.gov/public_info/facts/Cr6facts072711.html

6. U S Environmental Protection Agency (US EPA); Field Applications of In-Situ Remediation Technologies: Permeable Reactive Barriers, EPA 542-R-99-002, April 1999

7. US EPA; National Primary Drinking Water Regulations- consumer Fact Sheet on: Chromium, http://www.epa.gov/safewater/dwh/c-ioc/chromium.html

8. US EPA; Groundwater Issue; Natural attenuation of Hexavalent Chromium in Groundwater & Soils; by Robert Puls, 1994, EPA/540/S-94/505

9. US EPA; Groundwater Issue- Behavior of Metals in Soils, EPA/540/S-92/018, by Joan McLean and Bert E. Bledsoe

10. US EPA -Technology Innovation Program-Contaminant Focus-Chromium VI (Aug 15, 2007). http://www.clu-in.org/contaminantfocus/default.focus/sec/chromium_VI/cat/Overview/

11. Yi-Tin Wang; Hexavalent Chromium Reduction by Bacillus sp. in a Packed-Bed Bioreactor, Environmental Science & Technology; 31(5); 1446-1451. (Article)

12. USGS; John A. Izbicki, James W. Ball, Thomas D. Bullen, Stephen J. Sutley, Chromium, chromium isotopes and selected trace elements, western Mojave Desert, USA, 2008 http://ca.water.usgs.gov/news/Chromium-report.pdf

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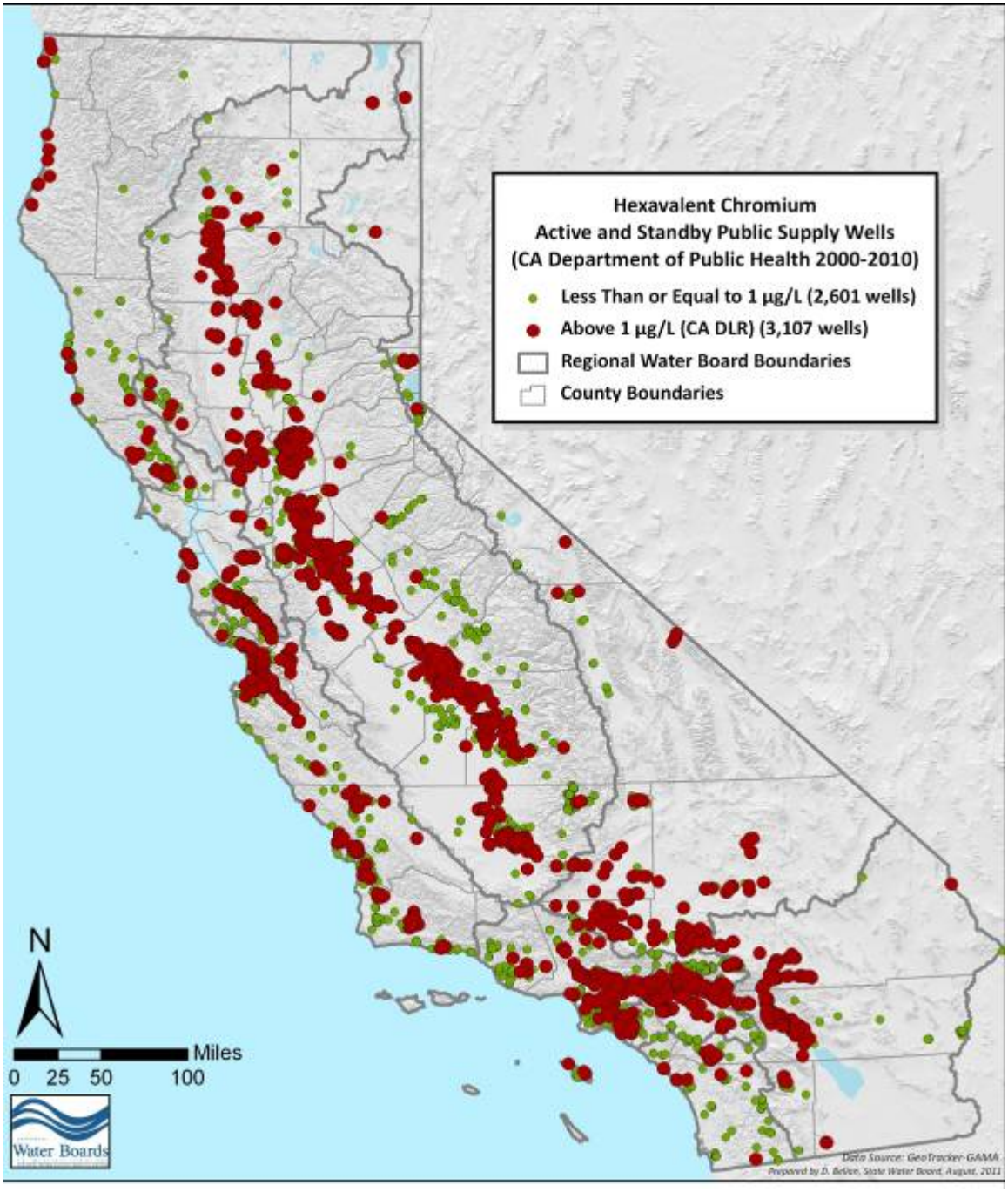
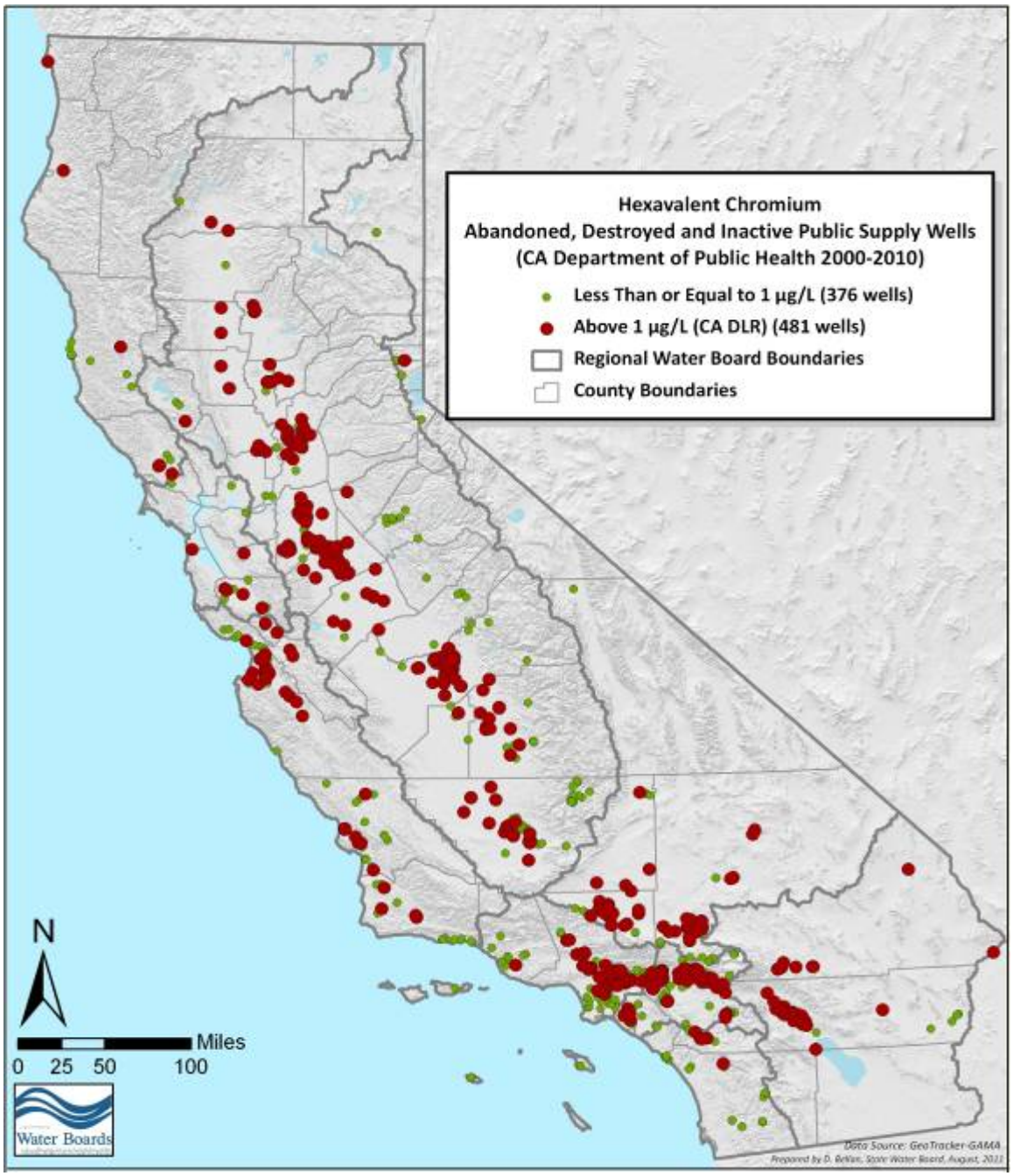


Active and Standby Public Supply Wells with at Least One Detection above the 1 µg/L DLR (3,107 wells)

Source: August 2010 well query of CDPH data using GeoTracker GAMA



Abandoned, Destroyed, and Inactive Public Supply Wells with at Least One Detection above the 1µg/L DLR (481 wells)

Source: August 2011 well query of CDPH data using GeoTracker GAMA